

CAN GLOBAL TEMPERATURE RISE BE LIMITED TO 2 DEGREES?

WHAT DO WE NEED TO KNOW AND HOW WELL DO WE NEED TO KNOW IT?

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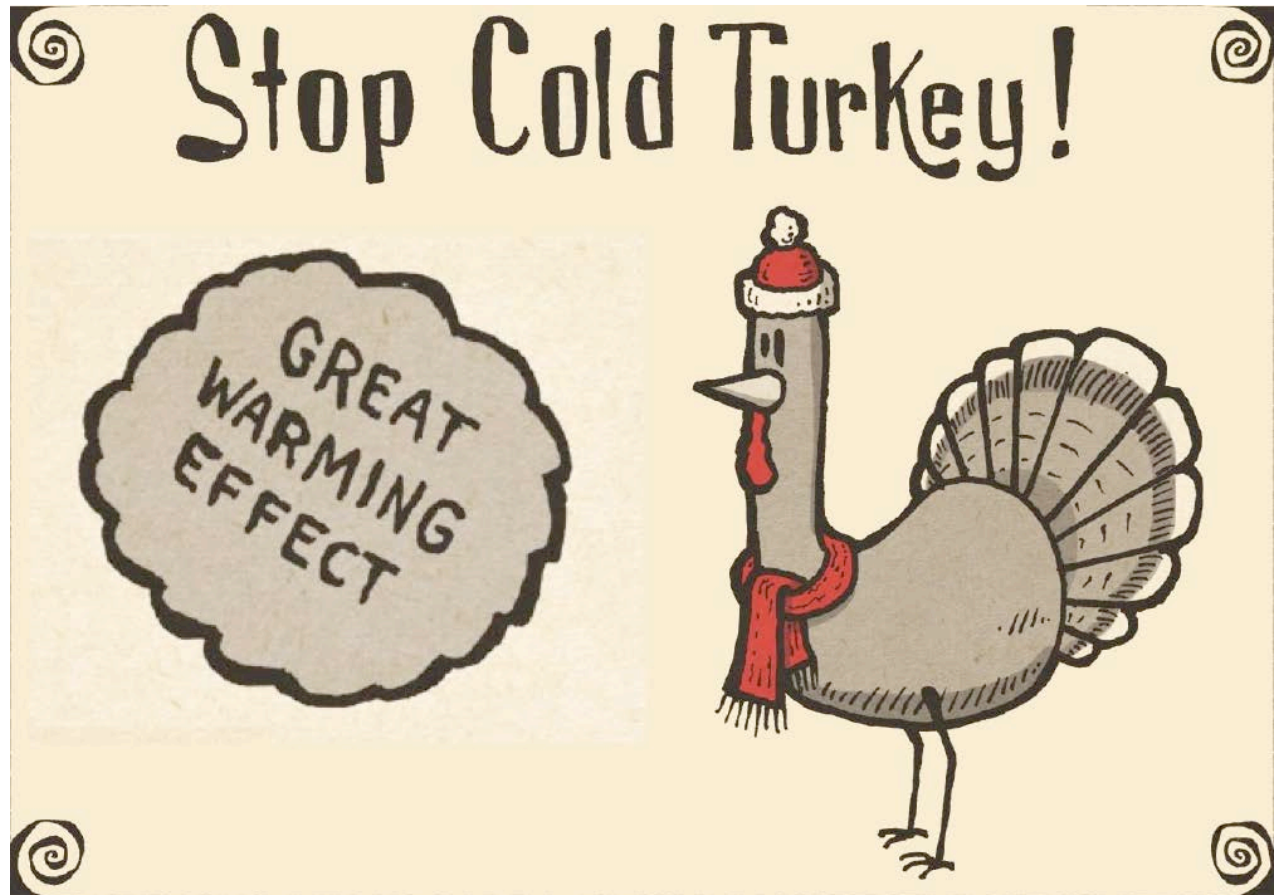


Santa Fe, NM, February 5-10, 2017

www.ecd.bnl.gov/steve

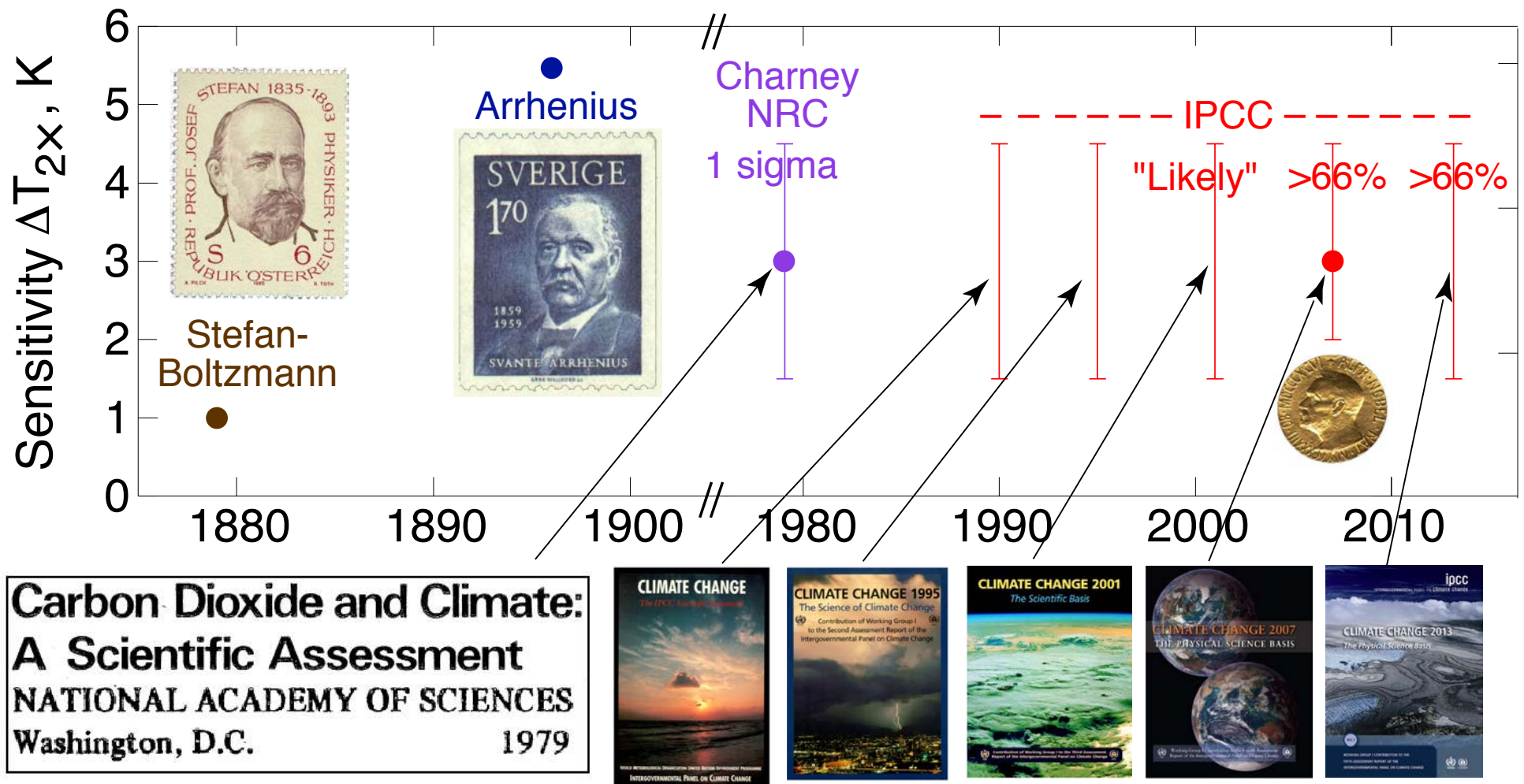
GEDANKEN EXPERIMENT

- Turn off all fossil fuel combustion.
- Turn off emissions of carbon dioxide.
- Turn off emissions of aerosols and aerosol precursors.
- What happens?



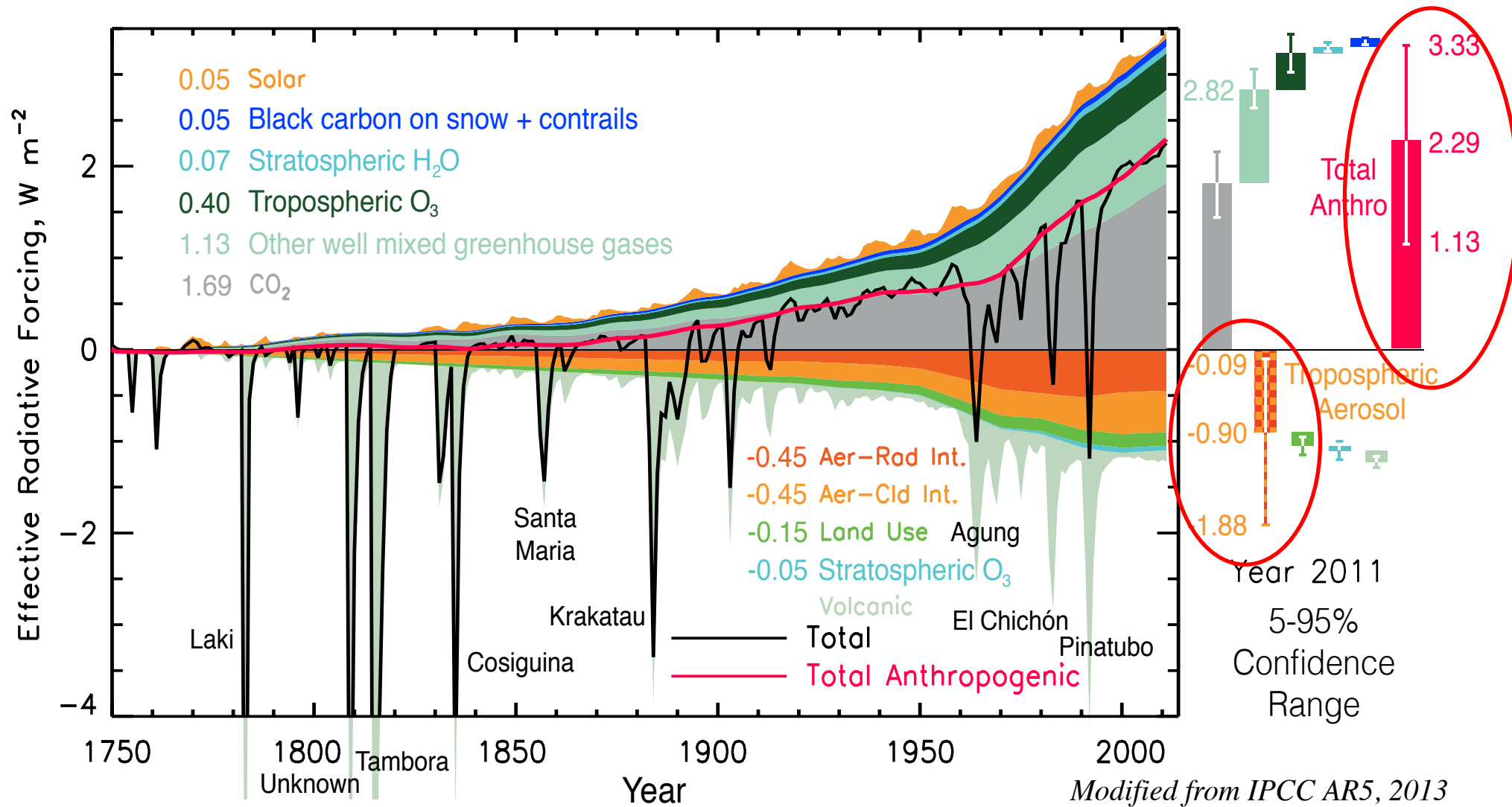
CLIMATE SENSITIVITY ESTIMATES THROUGH THE AGES

Estimates of central value and uncertainty range from major national and international assessments



Despite extensive research, climate sensitivity remains *highly uncertain*.

CLIMATE FORCINGS OVER THE ANTHROPOCENE



Greenhouse gas forcing dominates positive forcing.

Aerosol forcing dominates negative forcing.

Uncertainty in aerosol forcing dominates total uncertainty in forcing.



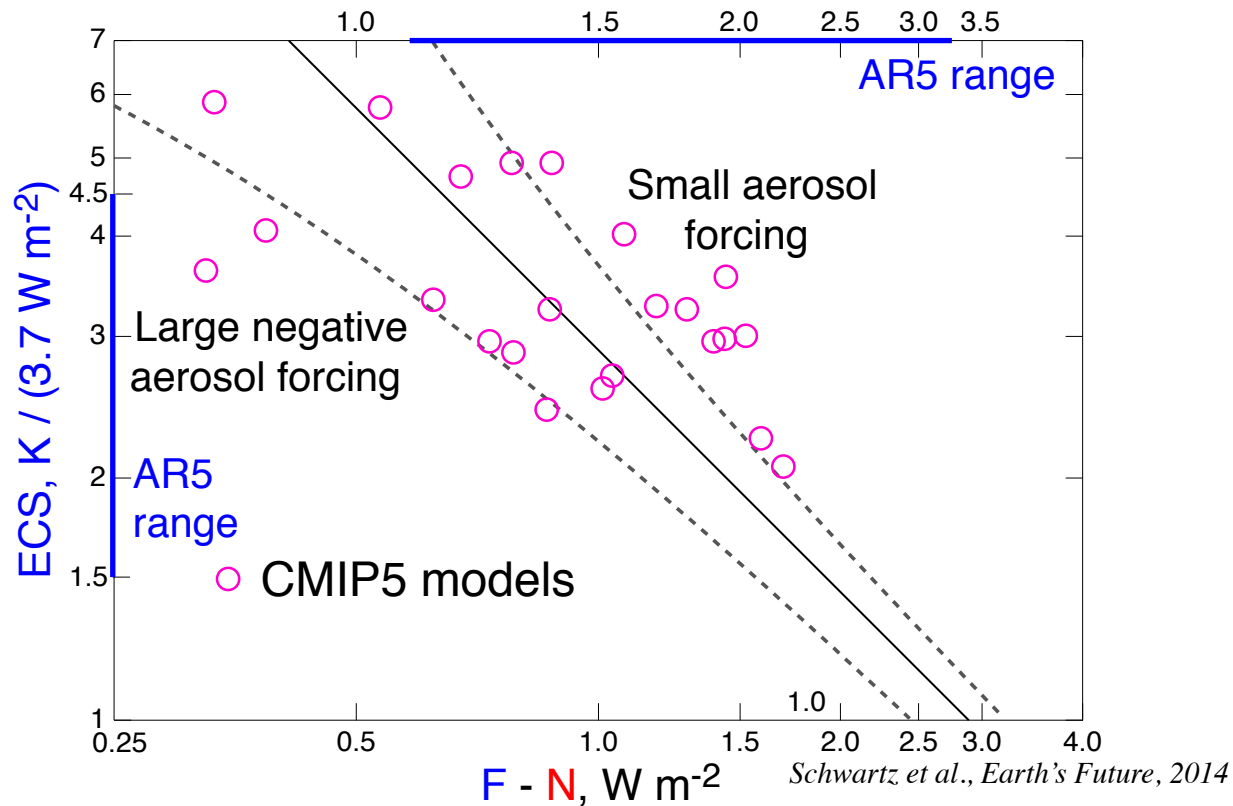
Uncertainty is an
uncomfortable position...

But certainty is
an absurd one.

– *Voltaire*

OBSERVATIONAL CONSTRAINTS RELATING ECS AND FORCING

$$\text{ECS} = (3.7 \text{ W m}^{-2}) \frac{\Delta T_s}{F - N}$$



ECS vs $F - N$ is straight line on log-log plot; slope = -1 .

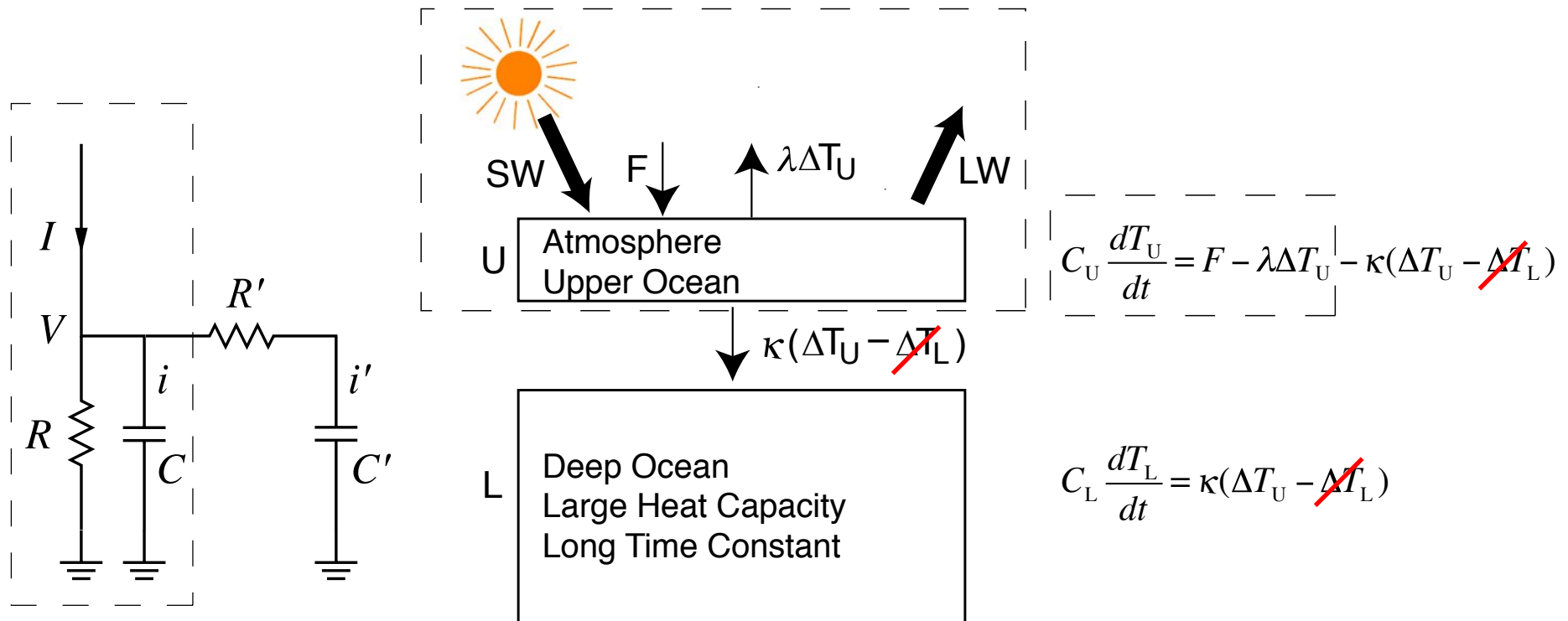
ΔT_s over 20th century, 0.78 K; net TOA flux N , 0.51 W m^{-2} .

Dashed lines account for uncertainties in ΔT_s and N .

Models are consistent with observations despite widely differing F and ECS.

TWO COMPARTMENT ENERGY BALANCE MODEL

Two Resistor–Capacitor circuit as analog to climate system



Flow of heat into large, deep compartment (current into large capacitor) acts in parallel to emitted longwave radiation (current through primary resistor) to decrease temperature (voltage) of upper compartment, until deep compartment (large capacitor) fills up.

Same model used to interpret GCM results by Gregory 02; Held *et al.*, 10.

KEY PROPERTIES OF THE CLIMATE SYSTEM

“Rule of Fives”

Component of climate system	Time constant, yr
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Deep ocean	500
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Upper ocean and troposphere	5
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Atmospheric carbon dioxide	50
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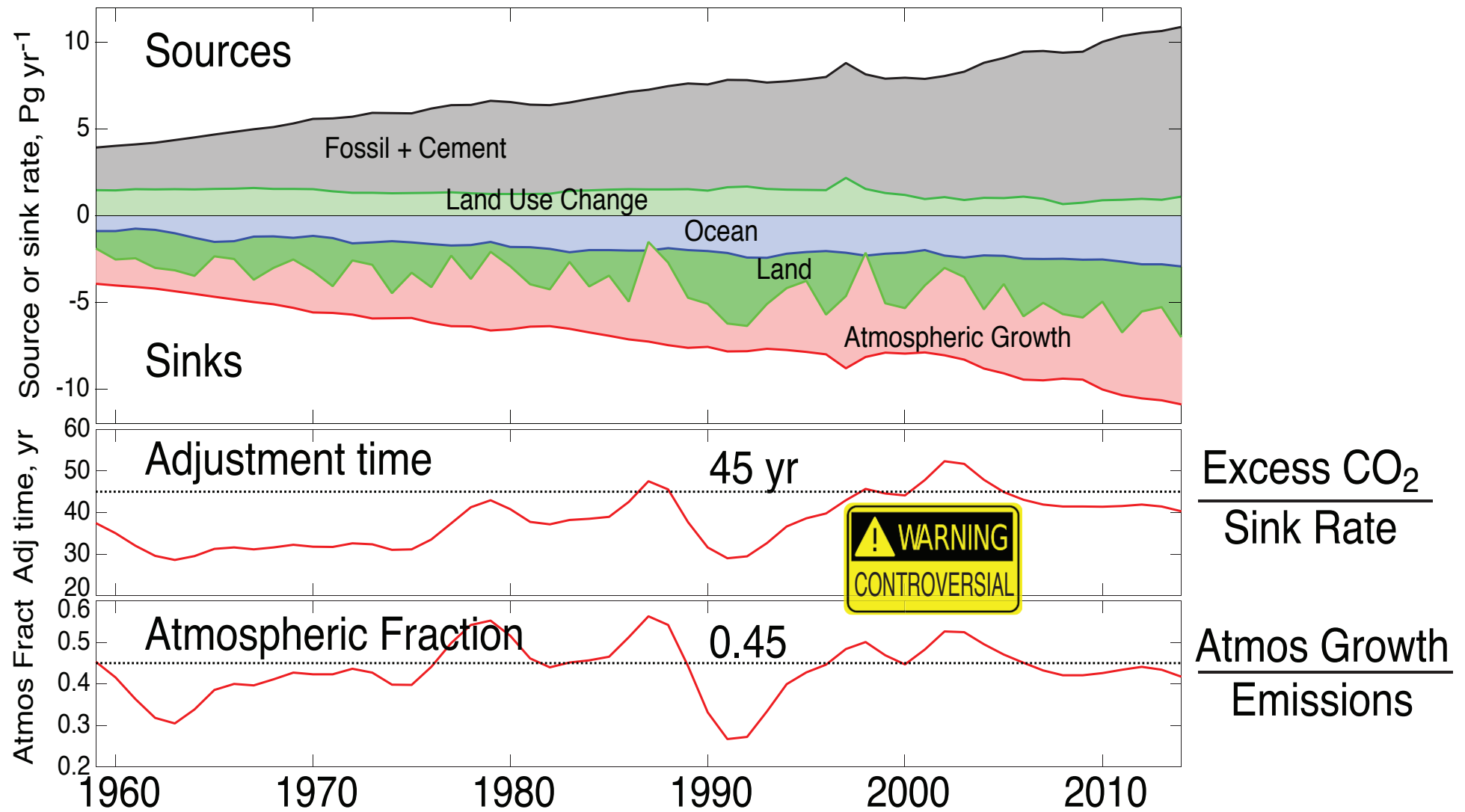
Tropospheric aerosols	1 week = 1/50
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Atmospheric fraction of emitted CO ₂	0.5
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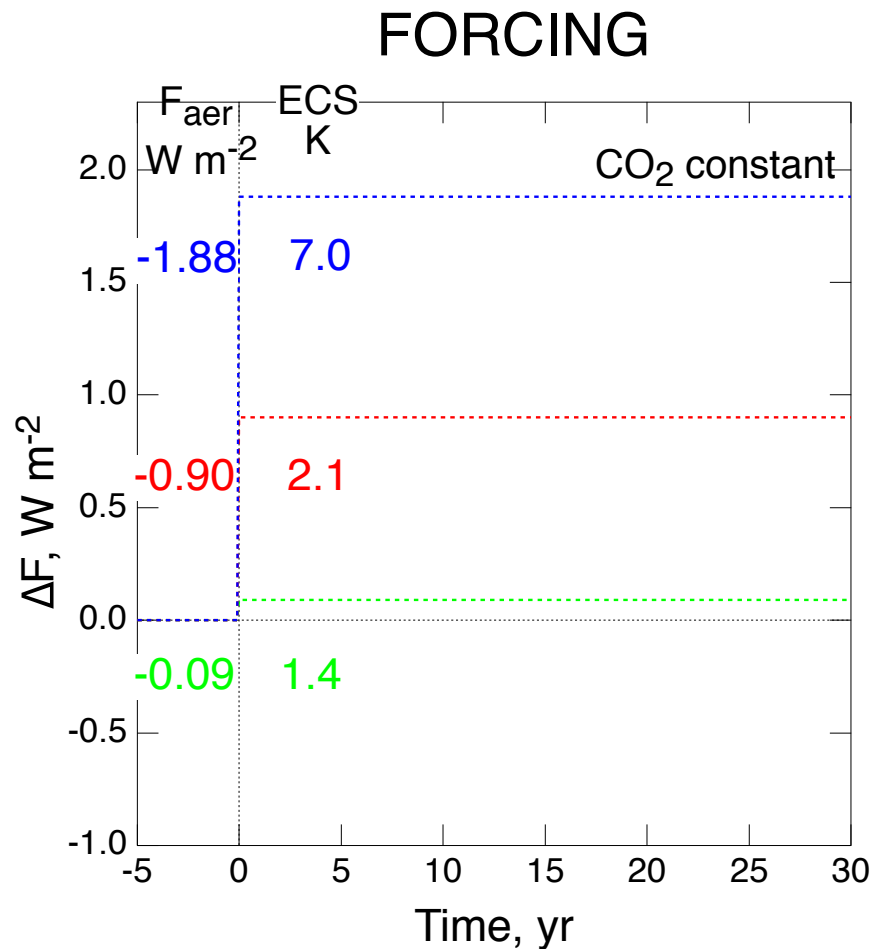


EMPIRICAL DETERMINATION OF CO₂ PARAMETERS

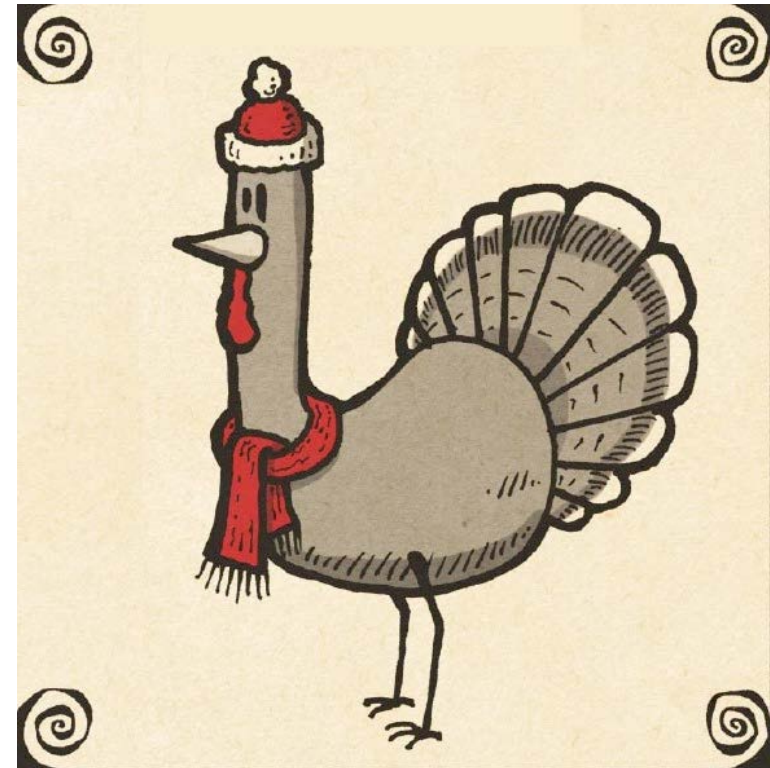


Data: Le Quéré et al., 2016; NOAA

ABRUPT CESSATION OF FOSSIL FUEL COMBUSTION



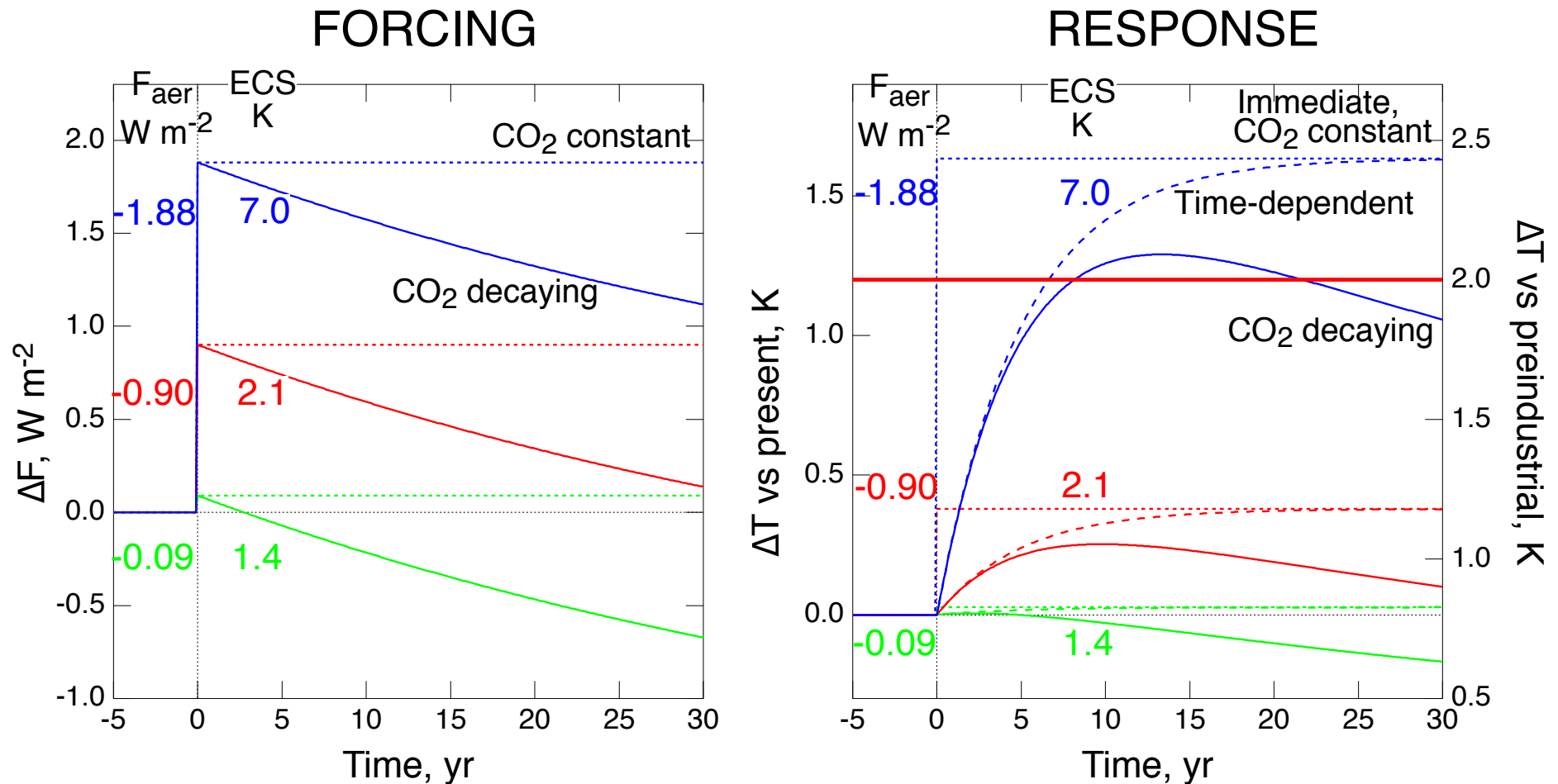
CO_2 emissions $\rightarrow 0$
Aerosol and precursor emissions $\rightarrow 0$



If aerosol forcing magnitude is low, climate sensitivity is low, and vice versa.

Cessation of negative aerosol forcing results in positive step-function increase in forcing.

ABRUPT CESSATION OF FOSSIL FUEL COMBUSTION

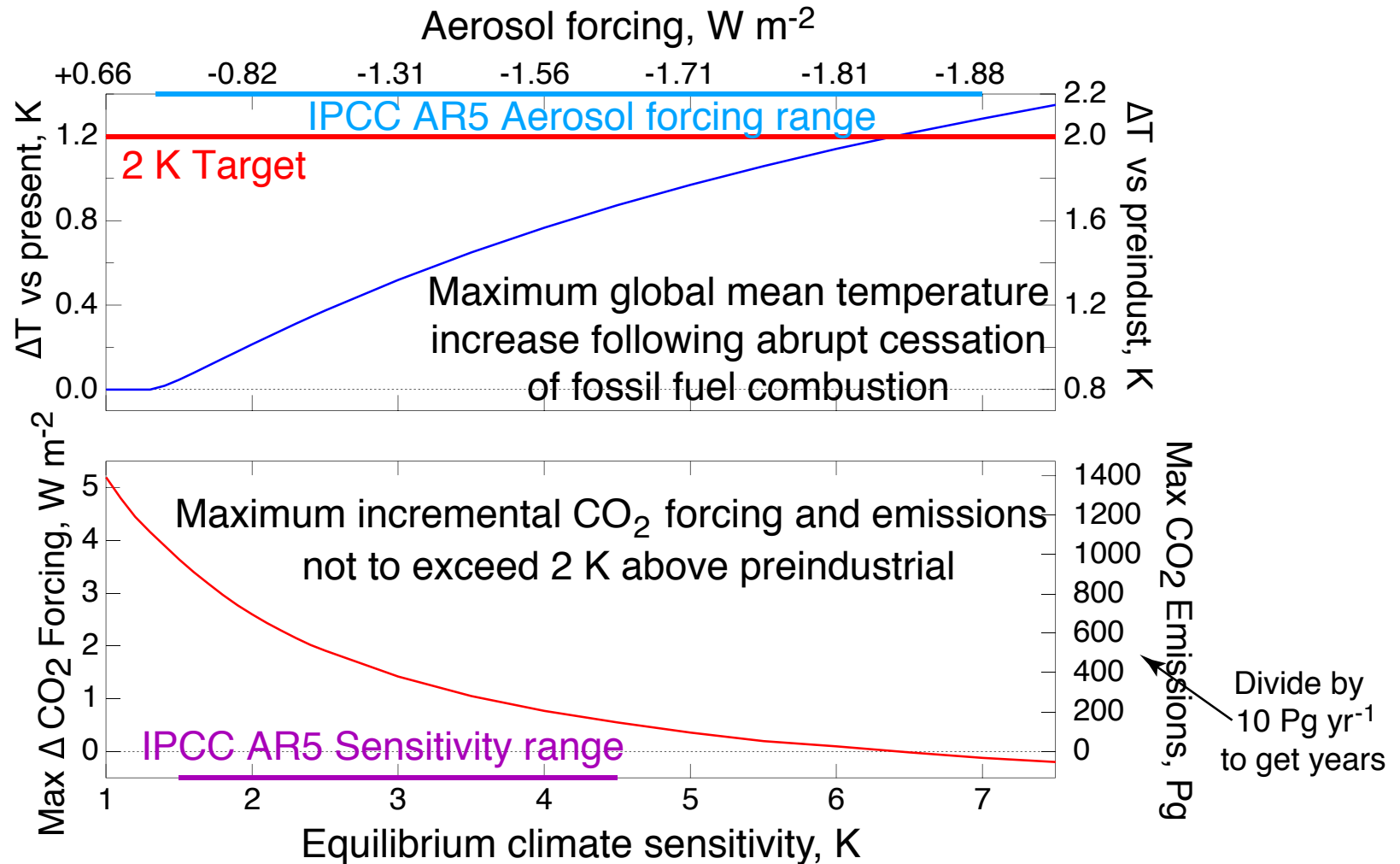
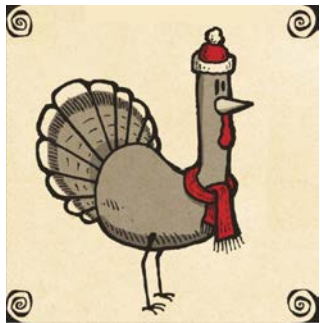


Committed future increase in global temperature depends strongly on climate sensitivity or, equivalently, current aerosol forcing.

If climate sensitivity is high, as required for aerosol forcing at the large end of the IPCC range, then 2 K target maximum would be exceeded even for immediate cessation of fossil fuel combustion.

MAXIMUM COMMITTED WARMING AND ALLOWABLE CO₂ EMISSIONS

Dependence on climate sensitivity or aerosol forcing



Strong dependence on climate sensitivity or, equivalently, current aerosol forcing. Might need to go “cold turkey” within 20 years, or possibly too late to avoid 2 K.

PROPOSITION FOR DISCUSSION

Climate Sensitivity is (remains) the single greatest source of uncertainty in determining allowable future greenhouse gas emissions consonant with not exceeding a given target increase in GMST.

